

a vision of the future

Sometime in the new century, humanity will know its place in the universe . . . and will begin the challenge of writing its future in the history of the cosmos. Our telescopes will have revealed in detail the most fundamental structures in nature: the galaxies and the stars. Life-bearing planets—if they exist—will have been at least tentatively identified. The next major step after detailed spectroscopy of planetary atmospheres must be imaging of their surfaces: even a dozen or so pixels in one direction across the face of an Earth-like planet orbiting a neighbor star would reveal continents and weather patterns, as well as seasonal variations. The optical designs for such an ambitious undertaking are not complicated, but pose enormous engineering challenges.

If there are new fundamental forces in nature that await discovery, we will have searched for them within the gravitational maelstrom of massive black holes and in the earliest moments after the Big Bang. Our most powerful x-ray interferometers will have revealed the detailed structure at the edges of black holes, and sub-millimeter interferometers will study the nature of gravity itself within the fossil remnant of the primordial fireball. The life story of our Milky Way galaxy, as its stars, planets, and life are built up from primordial atoms, will be much better understood.

Our most sophisticated robots will have traveled to the dark outer reaches of the Solar System and plunged beneath the icy surfaces of Europa and Titan, to seek out signs of organic activity, and perhaps, the struggles of life to maintain a foothold even in these forbidding environments. Closer to home, Mars will have been surveyed in detail, with sur-



The two Mars 2003 rovers will extend the surface exploration begun by Viking and Pathfinder. These new rovers will be able to travel 100 meters per day, and will carry scientific instruments to determine the geological context of rocks and soil and measure their chemical composition and fine scale structure—even scraping the surface off rocks to expose their unweathered interiors.

face samples returned to Earth for detailed study. Programs to survey the Red Planet for hidden resources of water will be well underway, as well as an extended geological and meteorological reconnaissance.

Our dynamic Sun and its surrounding planets will be understood as a system, including the effects of the Sun's life history on the origin and continuation of life in our Solar System. We will have gained the ability to predict and manage the effects of solar variability on Earth and on humans and machines in space. Our spacecraft will have ventured beyond the bubble of solar wind that surrounds the Solar System to take our first steps into interstellar space.

Thanks to technologies emerging today, Earthbound humanity will be able to participate actively in the great adventure of exploration. Our robotic emissaries to Mars and the other worlds in our Solar System will possess increasingly powerful capabilities for interaction with the home planet: virtual sight and sound, covering a broader spectrum of wavelengths and a far wider range of frequencies, will recreate on Earth the experience of exploring even the most forbidding environments in space. All our citizens will become space explorers.

At the same time, a new generation of technology may permit more



The Hubble Space Telescope (HST) was designed to be a serviceable spacecraft. An astronaut uses the Power Ratchet Tool on an HST bay door while replacing the observatory's flight computer.

individuals, for a greater variety of reasons, to travel into space. It may be that future steps in understanding our place in the cosmos will be taken by a partnership between

humans and machines in space. Complex optical systems, satellite subsystems, and instruments may be better updated, replaced, or repaired by human partners than

by even very advanced remotely-operated robots. Trained geologists on Mars may one day amplify the capabilities of robotic collaborators used for large-area surveying and rapid reconnaissance by digging below the surface of dry riverbeds and along the shorelines of ancient oceans in search of the history of a biology—if any—beyond Earth.

One day, after our first planet-finding observatories have beamed back images of warm, wet worlds in orbit around neighboring stars, our descendants will begin to contemplate humanity's destiny of discovery beyond the Solar System.

